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TEXTILE MACHINERY RESEARCH

AT THE

SOUTHERN REGIONAL RESEARCH LABORATORY

Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE

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TEXTILE MACHINERY RESEARCH AT THE SOUTHERN REGIONAL RESEARCH LABORATORY[1]

by

R. A. Rusca[2]

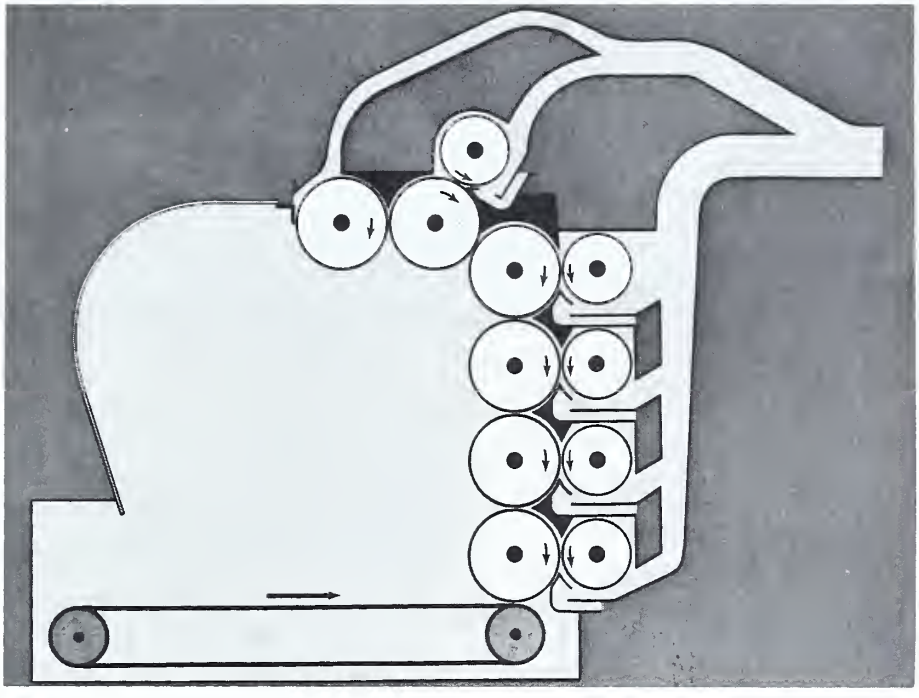

Figure 1.—*Schematic diagram of the SRRL Opener.*

INTRODUCTION

The Southern Regional Research Laboratory (SRRL) of the Southern Marketing and Nutrition Research Division, began operations in 1941. An essential part of the Laboratory's program to increase the utilization of cotton is the development of new textile processing equipment to raise the quality and lower the cost of cotton textiles. From 1941 to about 1947 the machinery development scientists devoted their efforts to military-associated projects such as designing equipment to produce nitrocellulose from any length cotton fiber and improving cotton cord pneumatic tires for military vehicles.

Research on processing machinery since 1947 can logically be divided into two periods: For 20 years the research was concerned with the development of new and improved machines for specific textile processes; and for the past 3 years the research has been concerned with development of a fundamentally new system for processing cotton directly from the bale into yarn.

CONVENTIONAL PROCESSING EQUIPMENT

In the development of equipment adapted to conventional textile processes, emphasis was on overcoming one of the major handicaps in cotton's competition with synthetics—foreign matter. Therefore, research concentrated on blowroom and cardroom improvements. Many of the resulting SRRL machines are used in the textile-producing countries of the world. Several of these machines will be discussed briefly.

Cotton Opener

The SRRL Cotton Opener (*23, 24*)[3] was developed to open and blend cotton and to facilitate improved cleaning by the mills' existing equipment (fig. 1). The design is based on the principle of

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[1]Presented at the afternoon session of the Textile Machinery Society of Japan Symposium, Osaka, Japan, July 15, 1970.

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[3]Italicized numbers in parentheses refer to Literature Cited, at the end of the publication.

loosely restraining a large mass of cotton, imparting momentum to the mass, and then plucking out small tufts of fibers from the mass at a rate that avoids fiber damage and neps. About the physical size of a standard hopper-feeder, the Opener processes cotton at a production rate of more than 1,000 kg. per hour.

The Opener became commercially available in 1951. It is a good opener and blender, but requires a large volume of air for satisfactory performance. About 400 Openers are in use throughout the world, processing about three million bales of cotton annually.

Opener-Cleaner

The Opener-Cleaner (*22, 25*) is basically the Opener with integral cleaning cylinders and an improved doffing system (fig. 2). It retains the opening and blending ability of the original Opener, and removes about one-third of the trash in the cotton at a production rate of 700 kg. per hour—sufficient for three or four picker lines. A new-type airbrush (*11*) doffs the cotton by mechanical and aerodynamic action and also provides a large part of the air needed for conveying the stock to the next process.

The Opener-Cleaner became commerically available in 1958, and it has gradually replaced the older model Opener. More than 400 machines are installed and processing about two million bales of cotton annually.

Aerodynamic Cleaner

The Aerodynamic Cleaner (*7*) was developed to add cleaning to SRRL Openers and to increase the cleaning efficiency of Opener-Cleaners. The device uses a specially designed duct and high-velocity air currents to eject motes and trash into a wastebox.

Installing the Aerodynamic Cleaner on the Opener requires major modification of the Opener (*12*).

Installing the Aerodynamic Cleaner on the Opener-Cleaner is simple and requires no modification of the machine. The Opener-Cleaner-Aerodynamic Cleaner combination removes about 40 percent of the trash at a production rate of 700 kg. per hour.

Granular Card

Perhaps the best known of the SRRL carding developments is the Granular Card, sometimes called the Flatless Card. The Granular Card (*5, 14, 21*) is a standard card with the flat assembly replaced by a rigid, fixed cover with a carding surface of sharp-pointed aluminum oxide granules. A small metallic wire roll and a waste-control licker-in cover complete the conversion. The apparatus eliminates flat strips, and materially reduces card maintenance and weight. A schematic diagram of the card is shown in figure 3. Introduced in 1958, the granular conversion proved too radical for most mills. During the

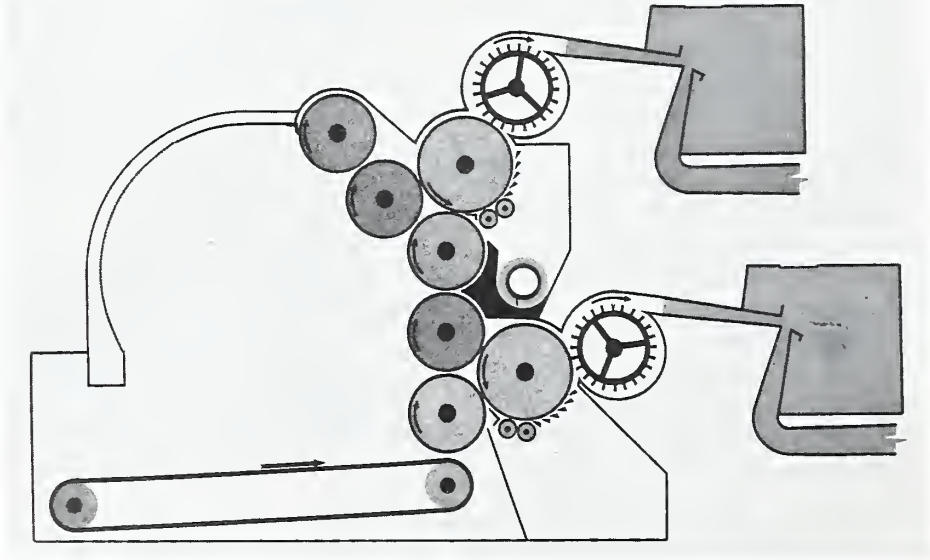

Figure 2.—*Schematic diagram of an SRRL Opener-Cleaner with Aerodynamic Cleaner.*

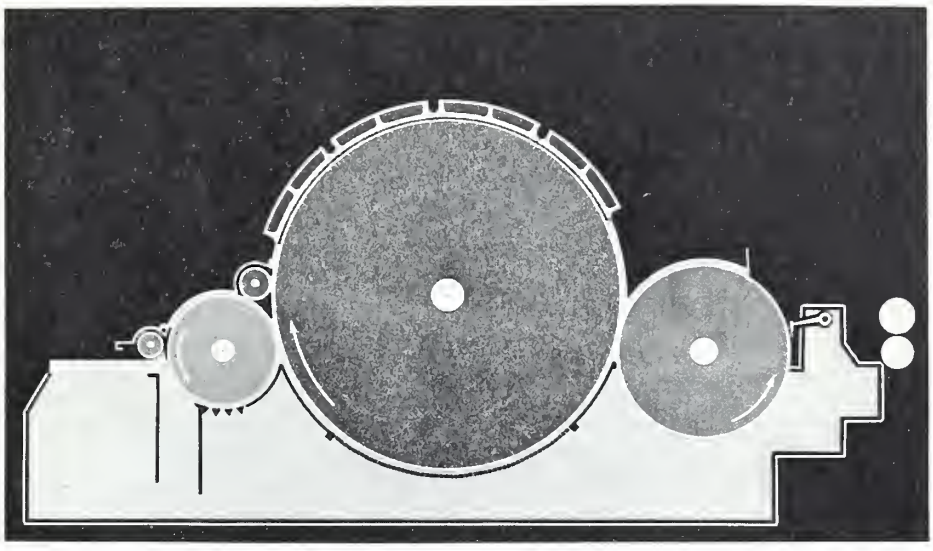

Figure 3.—*Schematic diagram of the SRRL Granular Card.*

past several years, however, the textile industry has learned how to use this type card; and in June 1970 more than 8,000 Granular Cards were operating on cotton, blends, and synthetic fibers in the United States.

Fiber Retriever

One of the problems with the Granular Card was that the lack of flats resulted in less cleaning by the card. The Fiber Retriever was developed in 1963 to increase card-cleaning efficiency (*13, 15*). It is a simple device that replaces the mote knives under the card licker-in (fig. 4). It reduces fiber loss, increases trash removal, and minimizes the possibility of damage due to lap end plucking. For best performance of the Fiber Retriever, a high licker-in speed and a waste-control cover are required.

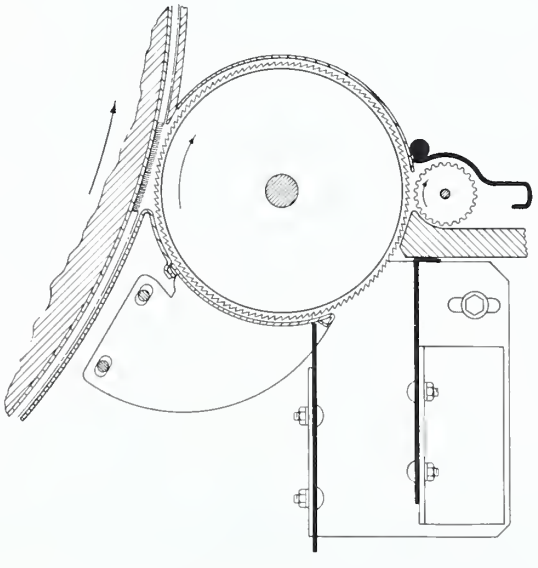

Figure 4.—*Schematic diagram of a Fiber Retriever.*

Licensed manufacturers of the Retriever report more than 12,000 installations in the United States, and many additional units have been constructed in mill shops. The device is of greatest benefit with high-production cards where excess fiber waste in the mote box and mechanical damage from lap ends are problems.

Bale-Opener—Blender

With the reduction in the number of preparatory processing machines and with fewer doublings, blending in recent years has become very important as a separate step in cotton textile manufacturing. The industry recognizes that efficient blending of many bales in the initial opening process is vital for maintaining processing efficiency in today's high-production mills.

Some years ago, SRRL initiated research to develop an improved method of blending cotton. This research has resulted in the development of a method and a machine in which layers from numerous bales of cotton are opened and blended within a single machine (*8, 9*). The Bale-Opener-Blender is designed to process layers of cotton, commonly referred to as a continuous sandwich bale. The commercial model blends up to 20 bales of cotton.

The basic principle of the machine is shown in figure 5. The cotton is moved within the Bale-Opener-Blender by an endless belt conveyor synchronized with side feed belts. Two pusher plates move the face of the bale back and forth during processing.

The cotton is advanced and held against vertical

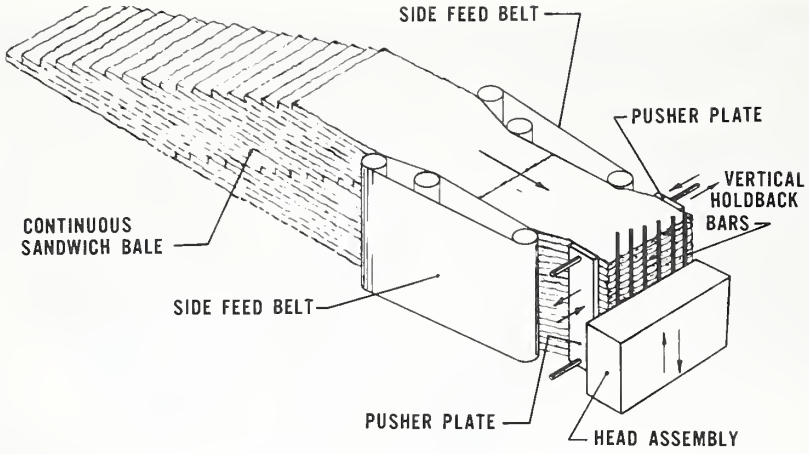

Figure 5.—*Pictorial diagram of the SRRL Bale-Opener-Blender.*

holdback bars. Hooked teeth on rotating processing cylinders within a head assembly pass between the bars, extracting tufts as the head moves up and down. Regulation of the force by which the bale is held against the holdback bars controls production rate. The depth of penetration of the processing cylinder teeth into the bale controls tuft size.

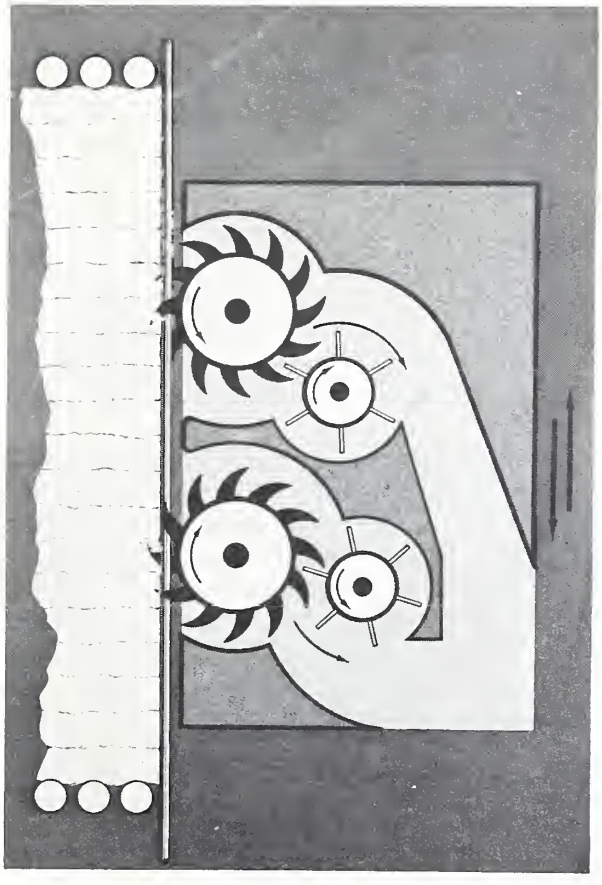

Figure 6.—*Schematic diagram of head assembly of the Bale-Opener-Blender.*

The head assembly (fig. 6) has two processing cylinders and two doffing cylinders that remove the cotton in small tufts and discharge the tufts into a single duct.

Production rate of the Bale-Opener-Blender is 600 kg. per hour, producing 2,000 to 5,000 tufts (1/2 to 1/5 g. each) per kg. of stock. The Blender was evaluated for 2 years in a large mill (*2*), and results indicate that it increases fabric quality and at the same time sharply decreases the amount of cleaning equipment needed in the mill (table 1).

The Blender constructed by SRRL for these tests is shown in figure 7. The machine is fully automatic and hydraulically powered (*26*) and can be stalled indefinitely without damage.

Nonlint Tester

The Nonlint Tester was developed in 1964 to meet the need for a rapid method of determining the foreign-matter content of cotton (*19,20*). The Tester is about 1 meter square and is portable (fig. 8). The test procedure involves weighing a 100-g. cotton sample, passing the sample through the Tester one time, and weighing the cleaned lint (*1*). A built-in scale reads directly in terms of percent nonlint content. One operator can test 15 to 20 sample per hour. An average of two samples provides the accuracy necessary for most mills.

The simple procedure, coupled with reasonable accuracy, makes the Nonlint Tester useful for quality control and research needs.

NEW PROCESSING SYSTEM

The cost of cotton yarns and fabrics is as important to the utilization of cotton as is the cost of cotton at the farm level. And the cost and quality of yarns and fabrics depend in large measure upon textile processing equipment and methods.

Table 1.—*Effect of Bale-Opener-Blender (BOB) on product quality*

Processing condition	Neps	Slub count	Quality change from control[1]	
			Yarn	Fabric
	Percent free	*Points/100 yd.*	*Percent*	*Percent*
Standard line:				
Control, 43-bale blend	68	7.7	–	–
BOB, 20-bale blend	80	4.7	+36	+25
Chute-fed cards:				
Control, 43-bale blend	64	23.3	–	–
BOB, 20-bale blend	76	23.3	+16	+16

[1]Based on standard of the Textile Distributors Institute and the National Federal of Textiles.

Source: Beaudrot, C. L. (*2*)

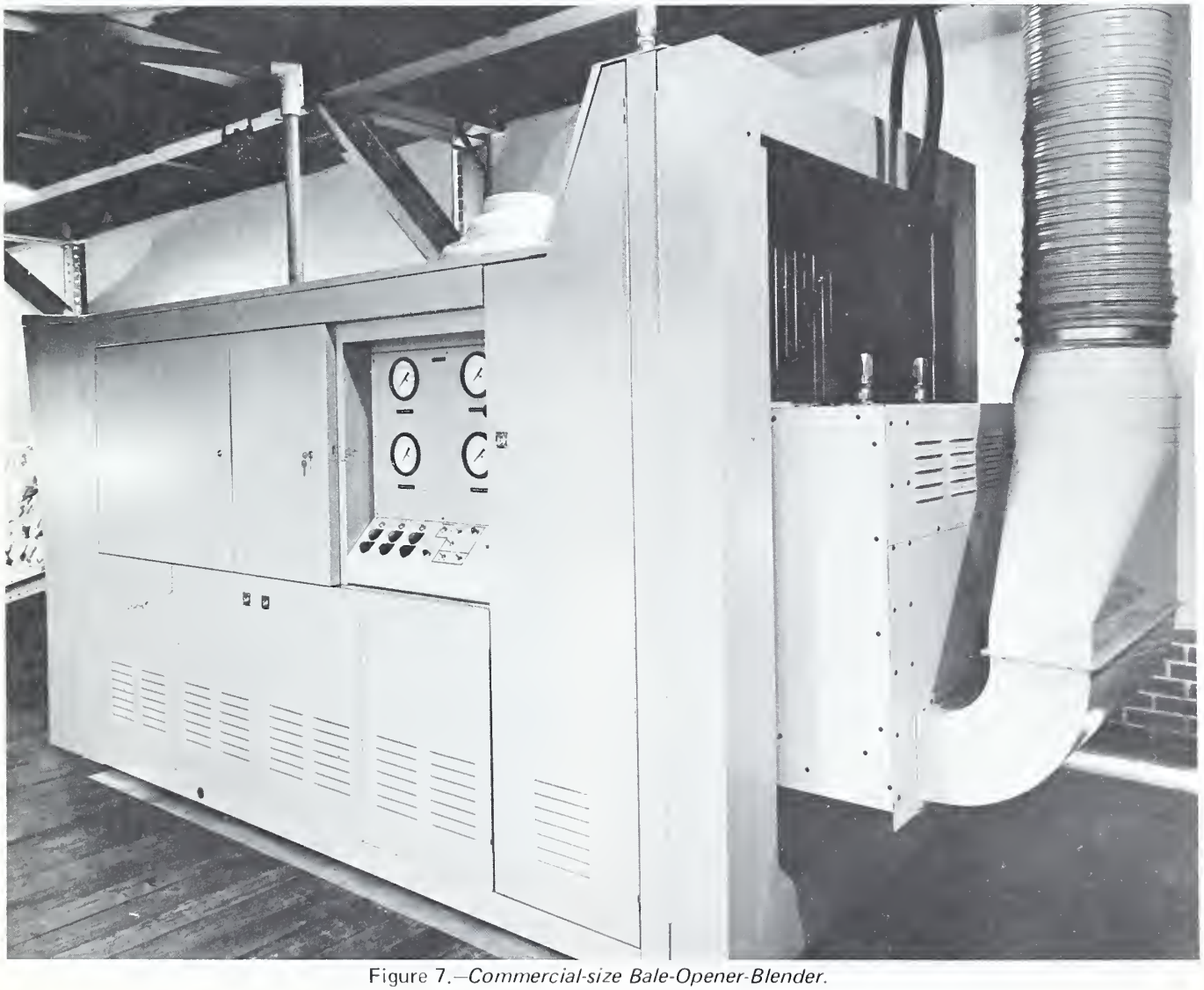

Figure 7.—*Commercial-size Bale-Opener-Blender.*

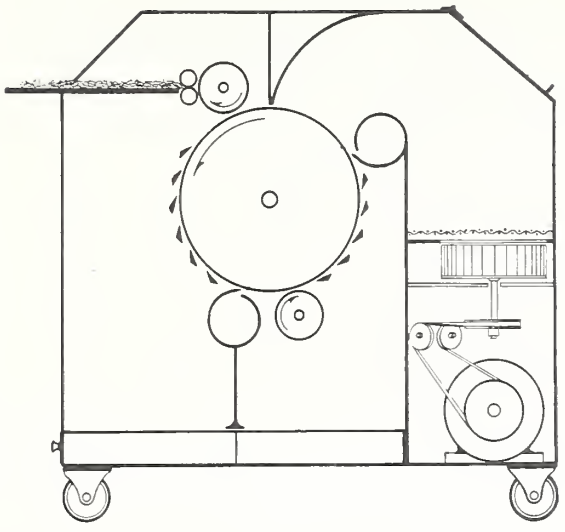

Figure 8.—*Schematic diagram of a Nonlint Tester.*

For many years (*16, 17, 18*) I have been convinced that the existing system for processing cotton into textiles has reached the point where drastic reductions in manufacturing costs and increases in product quality are not likely to be achieved by modifications or combinations of conventional machines, or even by the development of improved new machines that must fit into the existing system.

With this objective in mind, a pioneering research program was undertaken in 1967 by the Laboratory to obtain fundamental information that could lead to the development of highly efficient methods of processing fibers into yarn. For the most part, the research has been concerned with investigations of ultrasonic, aerodynamic, and electrostatic forces and their effects on the physical and chemical properties of cotton fibers. Although only a modest beginning has been made on this basic research program, promising findings and leads toward developmental research have been obtained.

Ultrasonic Research

Because basic information on the subject of ultrasonic research was not available, a comprehensive study has been made of the effect of sonic and ultrasonic radiation on cotton fibers in liquids (*3*) and gases (*4*) on the physical and chemical properties of the fibers. In the study of fibers in liquids, the fibers were treated in deionized, degassed water at 13 to 800 kHz for 7 minutes to 42 hours, at energy densities of 10 to 60 watts per liter, and at cavitation intensities of 30 to 220 cavits.

Small specimens (0.5 g.) were irradiated in an apparatus that consisted of two T-shaped Pyrex glass cells, each 18 cm. long and with an internal diameter of 7.5 cm. For treatment in the low frequency ranges (13 to 136 kHz), a double-face transducer of the Langevin sandwich type was mounted between the two sample cells. For treatment in the high frequency range (323 to 800 kHz), the Langevin transducer was replaced with a thin zircon titanate disk. The specimen was rotated at 5 revolutions per minute to provide uniform treatment.

Large specimens (3.5 g.) were treated in an apparatus that consisted of five vertical Pyrex glass cylinders irradiated from the bottom by a flange-mounted transducer. Each cylinder contained the cotton specimen and 2 liters of degassed water.

After treatment, the specimens were air-dried and tested by the American Society for Testing and Materials procedures for tensile strength, fiber fineness, fiber density, moisture regain, water of imbibition, chemical degradation, alkali swelling, and dyeing properties. Optical and electron microscopic examinations were also made.

The findings can be summarized by saying that ultrasonic treatment did not significantly affect cotton fibers in terms of textile processing or finishing, except for one narrow low frequency range. Treatment at approximately 30 kHz at an energy density of 20 watts per liter, and at a cavitation of 200 cavits for 24 hours caused fiber modification of the type associated with compressive fatigue (fig. 9). Continued irradiation seriously degraded the fiber.

Exposure of the cotton to airborne sonic and ultrasonic waves by the apparatus shown in figure 10 was found to cause no significant changes in fiber properties until the combustion temperature of the cotton was reached. This was true for a low frequency of 200 Hz to a high frequency of 40,000 Hz, 0.1 to 1 watt per square centimeter, and in atmospheres of air, oxygen, and nitrogen.

Efforts to remove foreign matter by sound energy were unsuccessful because of the rapid sound degradation and damping phenomena of sound energy in gaseous media.

This basic research has demonstrated that ultrasonic forces can be used on cotton without damage to the cotton, and has opened the door for the use of such forces in manipulating fibers in a new-type processing system.

Aerodynamic Research

The fundamental aerodynamic research conducted to date (1971) has been directed toward

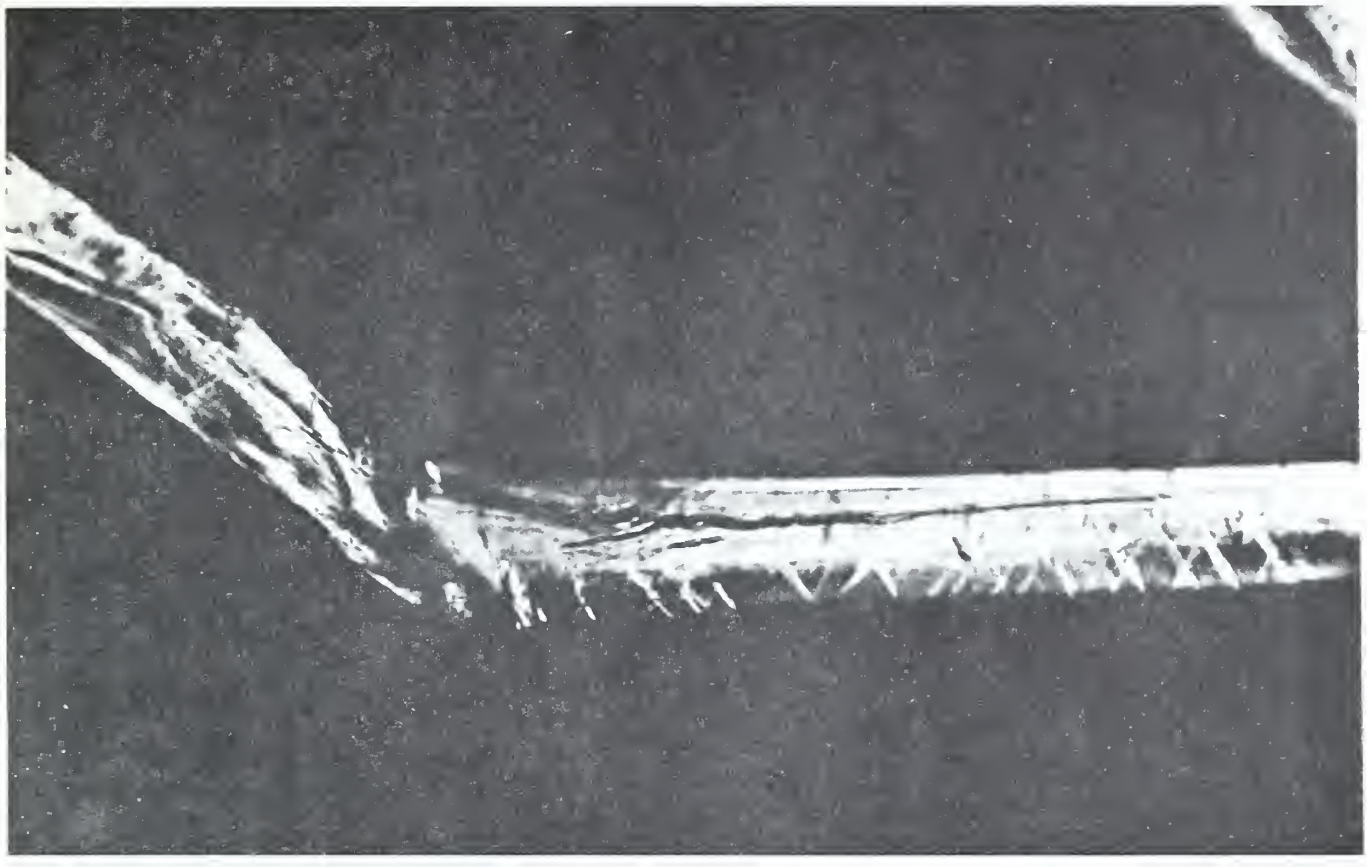

Figure 9.—*Photomicrograph of cotton fiber treated at 30 kHz for 24 hours (500 magnification).*

developing an understanding of how these forces can contribute to opening, alining, and conveying lint cotton (*6, 10, 27*).

A theoretical analysis was first conducted to formulate the basic laws of motion of small objects in an airflow. General equations were solved for very long slender ellipsoids experiencing motion along their three principal axes. These results were applied to computing the load factors that fibers might experience when subjected to air velocity differences.

The acceleration of a fiber was found to increase inversely as the square of its diameter and to be a weak function of its length-to-diameter (slenderness) ratio. Also, the time required for a fiber to reach within 1 percent of the air velocity was determined. For example, a fiber attains the speed of the surrounding air in about six one-thousandths of a second. A cotton clump or heavy foreign matter will attain the same speed in the same time; however, the lag or response time for the clump or foreign matter is somewhat longer than for a fiber.

This phenomenon was applied to specially shaped ducting with abrupt flow fields, and the streamlines of the air and the trajectories of particles were evaluated. For this investigation a dispersed cotton-air mixture was induced to flow through straight ducts with smaller branching ducts and around right-angle corners. Figure 11 shows the flow of cotton in a straight duct with small branching ducts, and figure 12 shows the behavior of cotton moving around a corner.

One area in aerodynamics thought to have an important application in the manipulation of cotton fibers is the dilation effect. If the air in a given mass of unopened cotton is made to flow outwardly, it will produce outwardly directed forces on the fibers in the mass, and these forces will expand or open the cotton mass. Dilation is the flow corresponding to this expansion of a given mass of air as its density decreases.

A sample of cotton was cut from a bale and placed in the center of a cylindrical pressure chamber that had means for alternately pressurizing and depressurizing from each end. Cycles of pressure-depressure induced a symmetrical dilation of flow into the cotton mass that produced a pulling apart or opening of the mass. Repeating this cycling many times resulted in a gradual opening of the sample of cotton.

A diagram of a dilation chamber and wave flow

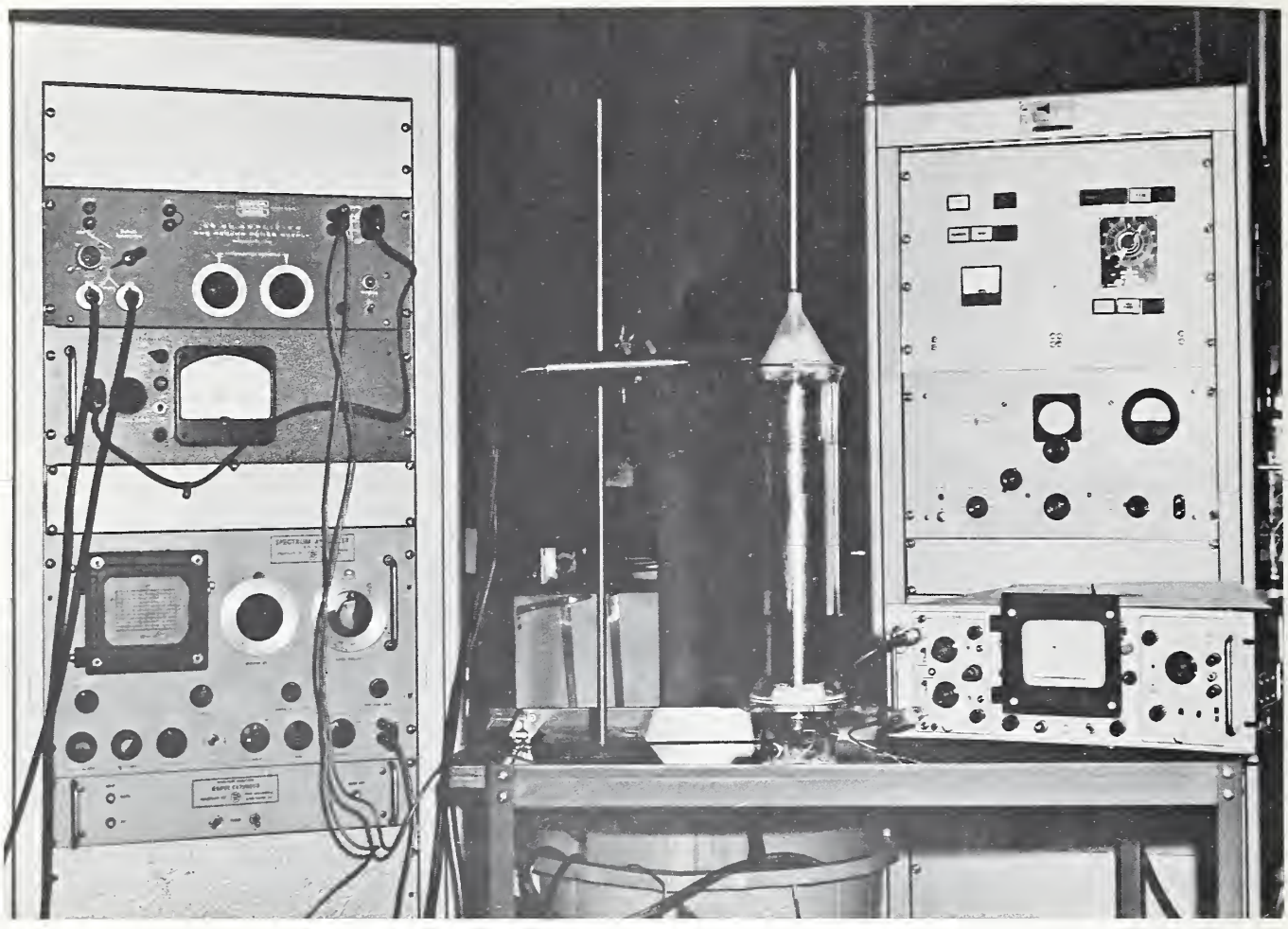

Figure 10.—*Apparatus for ultrasonic treatment of cotton fibers.*

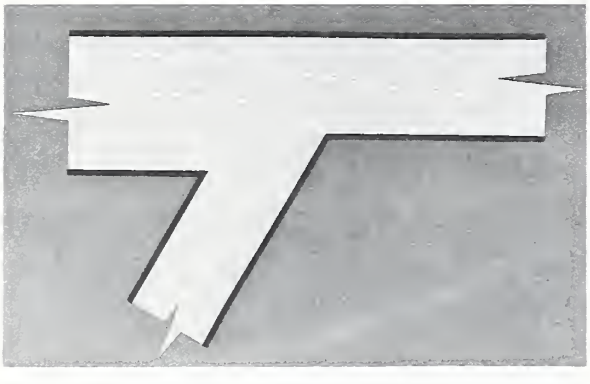

Figure 11.—*Airborne fiber flow in a straight duct with branching ducts.*

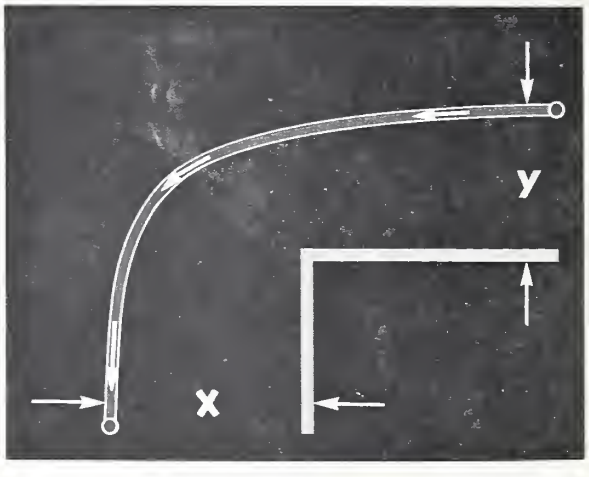

Figure 12.—*Airborne fiber flow around a right-angle corner. Y is the distance of the fiber from the duct side at the input, and X is its distance at the output.*

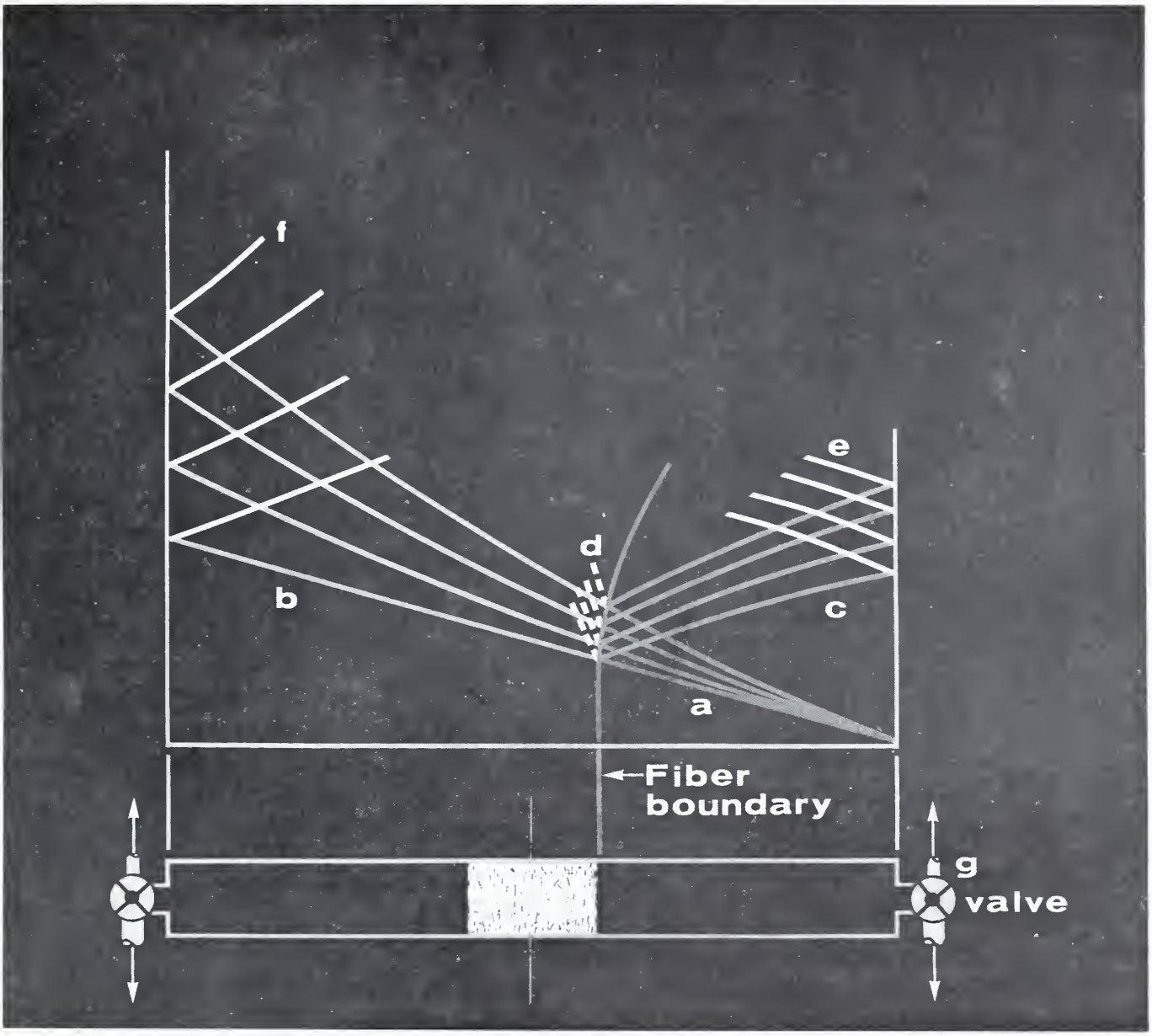

Figure 13.—*Diagram of reflected and transmitted waves from a one-dimensional dilation chamber (See text for explanation).*

are shown in figure 13. The major features of flow in the dilation chamber are illustrated by a wave diagram of events of the early time period of the chamber, as follows:

a. Initial expansion wave fan.
b. Air propagation waves transmitted through the fiber face.
c. Air expansion waves reflected from the fiber face as expansion waves.
d. Fiber expansion waves.
e. Air expansion waves reflected at end walls as compression waves.
f. Air expansion waves reflected from the axis of symmetry.
g. Valve.

Both the corner flow and dilation flow offer promising fields for further research. The results suggest the possibility of opening bales of cotton into controlled-size tufts by means of a single, large dilation chamber.

Electrostatic Research

Electrostatic phenomena have intrigued textile researchers for a long time. In recent years, electrostatic flocking and dust filtering have become commonplace, but otherwise electrostatics is used very little in textile processing. Research at SRRL is primarily to determine the fundamental effects of electrostatic forces on the physical properties of

cotton fibers.

Of particular interest are electric fields that produce ozone upon silent discharge. Samples of cotton have been subjected to ozone-generating electric fields and to ozone alone. The 100-g. cotton samples were treated in a 15-cm.-diameter Pyrex tube at ozone levels of 7, 14, and 21 mg. per liter for 5-, 10-, and 15-minute durations.

For the ozone-generating electric field treatment, a 60 kV d.c. power supply provided the field between two parallel plate electrodes with a 5 cm. air gap. The 100-g. cotton samples were spread uniformly between the plates and irradiated at potential gradients of 4, 6, and 8 kV per cm. for 2-, 5-, and 10-minute durations.

Standard tests of physical properties, including fiber friction, showed no significant variation in values for all experimental conditions.

Electron micrographs revealed some differences in the surface of the fibers exposed to ozone and to electric fields compared with the surface of untreated fibers, but apparently there was no effect on fiber strength or sliver drafting tenacity. Within the 0- to 60-kV range studied, electrostatic forces can be used without damage to cotton fiber in a textile processing system.

Research is now in progress on shaping electrostatic fields, using mathematical models and computer-analysis techniques. An example of a computer-plotted, shaped-field model is shown in figure 14.

The shaped-field technique was used in an experimental, laboratory model, electrostatic apparatus designed to fractionate cotton into long-fiber and

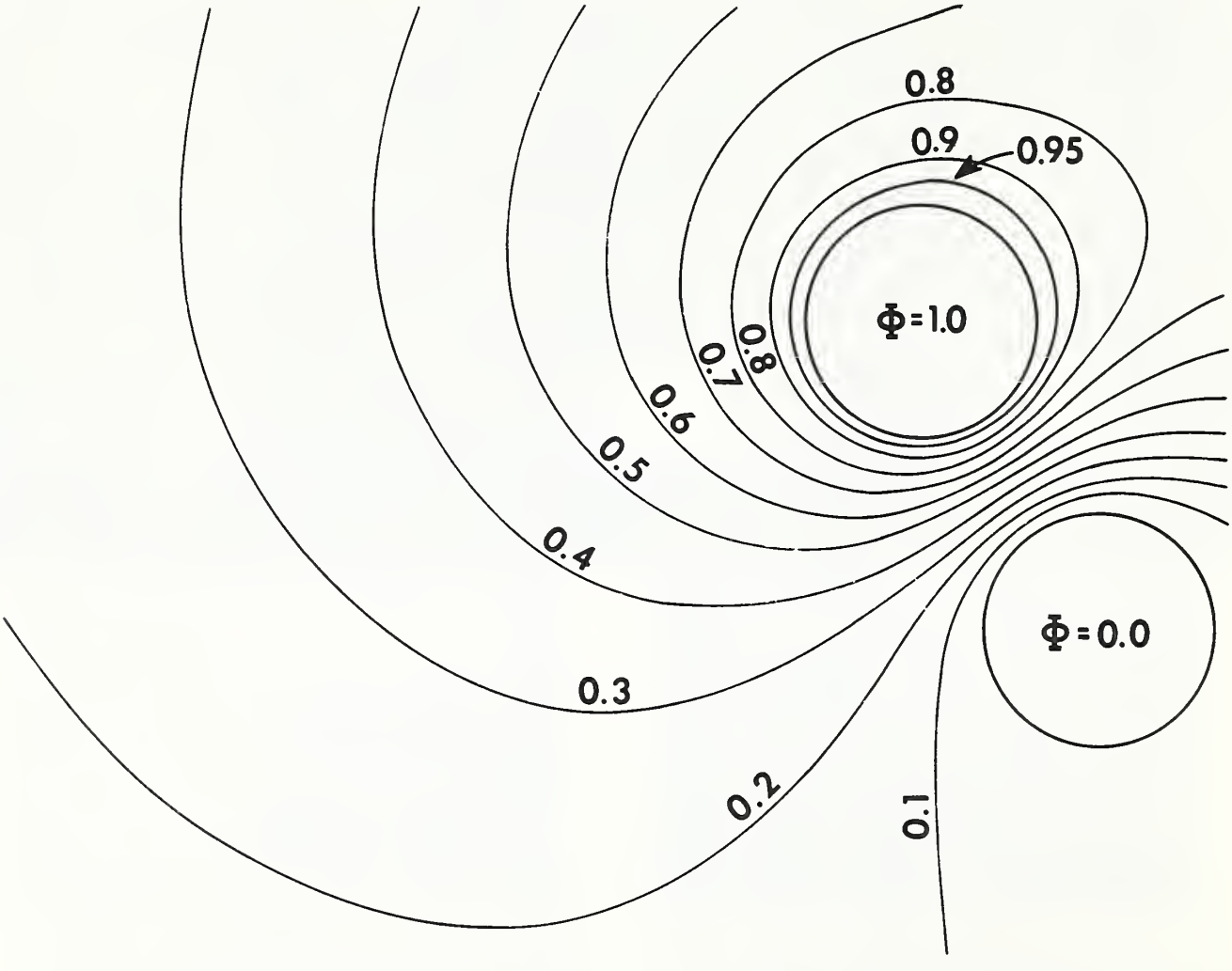

Figure 14.—*Shaped electrostatic field model plotted by a computer.*

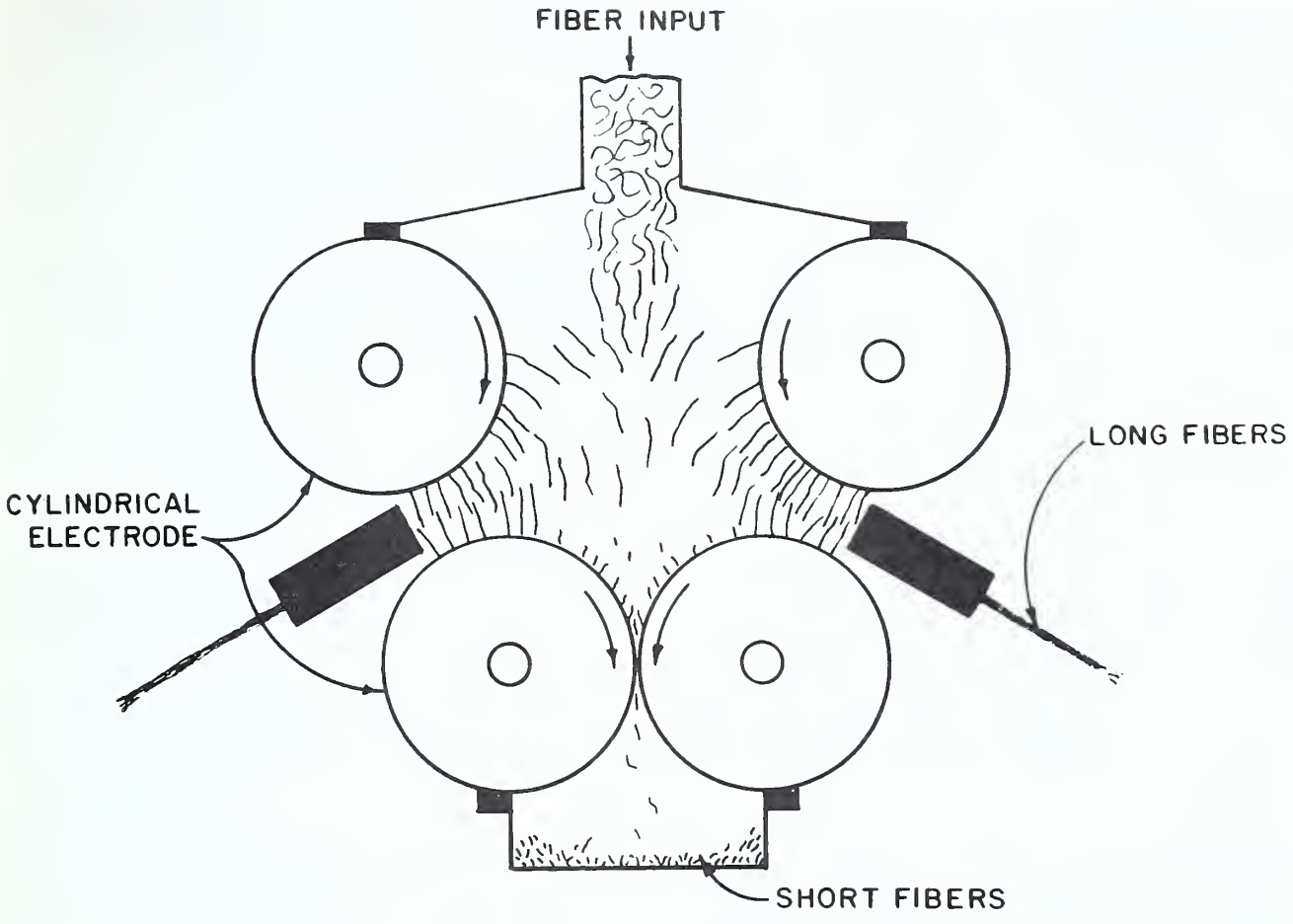

Figure 15.—*Schematic diagram of apparatus for fractionating cotton into long- and short-fiber components.*

short-fiber components. A schematic diagram is shown in figure 15, in which pairs of rotating electrodes provide nonuniform fields.

Once in the field the long fibers migrate to the region of high intensity and the short fibers are carried by the rotating cylindrical electrodes to the region of low intensity. Nonconductive doffers remove the long fibers, and short fibers fall into a collecting box. Fiber-length distribution before and after short-fiber removal is plotted in figure 16.

This technique removes from 20 to 45 percent of the short fibers, varying with the cotton and the production rate. Yarn strength is increased up to 10 percent and ends down is decreased up to 20 percent, depending on the original short-fiber content. The results indicate what can be accomplished with electric static fields.

Of far greater significance than the removal of short fibers from cotton is the fact that this experimental electrostatic process replaces all textile processing equipment from opening through drawing. Fed with cotton directly from the bale, the small machine produces a clean, relatively nep-free strand with excellent fiber orientation and superior fiber-length distribution. It must be emphasized that the apparatus is crude, the strand is non-uniform, the production rate is laboratory scale, and many problems must be overcome before a practical machine is developed. But the potential of this development is exciting. It could eliminate all conventional opening, cleaning, carding, and drawing machinery, which would be a gigantic step toward a truly continuous cotton processing system.

SUMMARY

Textile machinery manufacturers are eager to develop and produce new equipment, and the economic climate of the spinning industry is favorable for acceptance of innovations. The 1970-80 decade will be a period of rapid, exciting change in methods of processing textile fibers. Whether by the use of ultrasonic, aerodynamic, electrostatic, or some other approach, one of the greatest contributions of

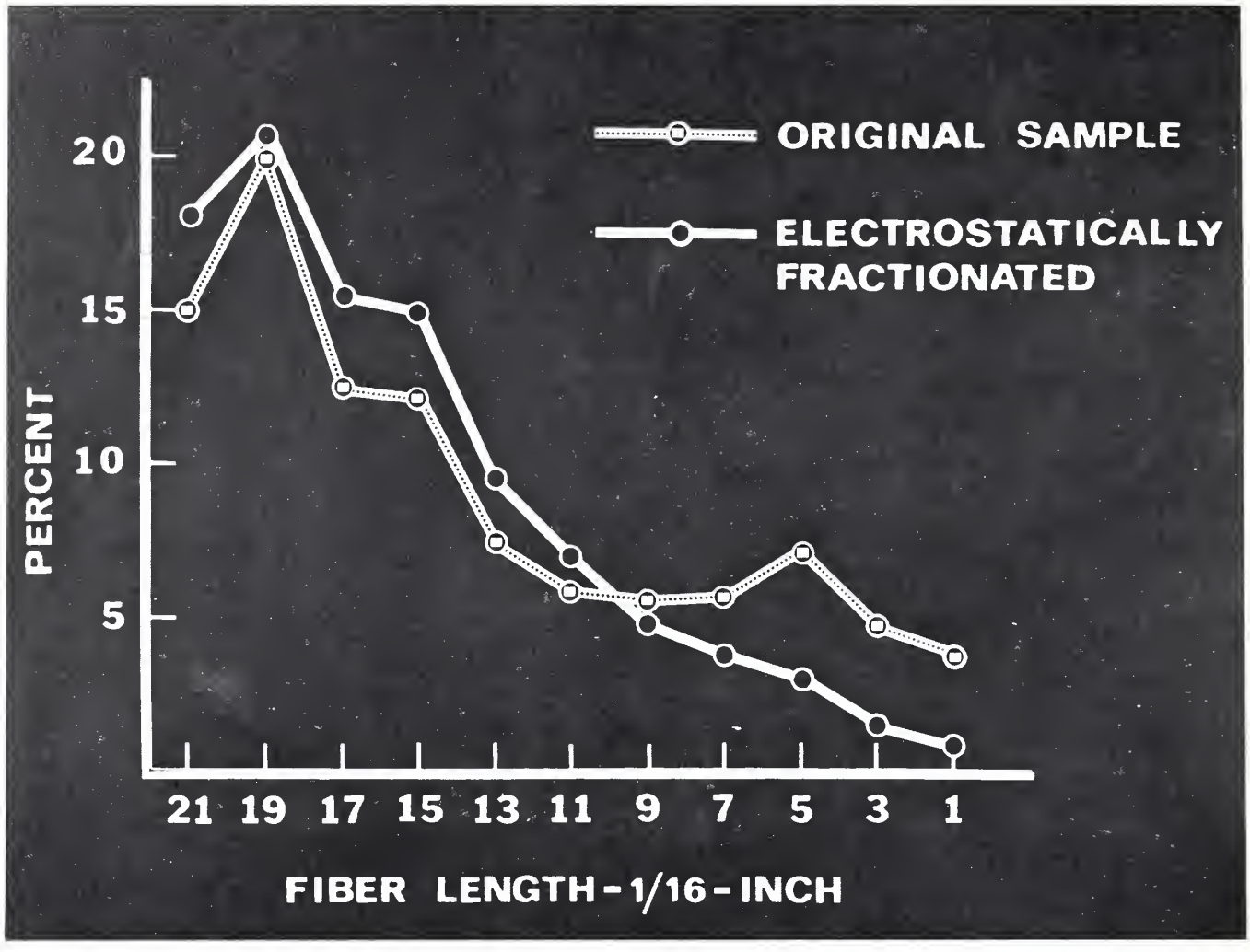

Figure 16.—*Fiber-length distribution curves, before and after short-fiber removal.*

the next generation to improving the competitive position of textiles will be the development of a fundamentally new system for inexpensively processing fibers into uniform, defect-free textile yarns.

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